of atoms. What does this tell you about the relative masses of copper and aluminum atoms? The number of atoms in 0.20 g of aluminum EQUALS the number of atoms in 0.71 g of copper. How many times more massive is a copper atom than an aluminum atom? (You may wish to compare

differences in the data and calculations among the groups in the class.

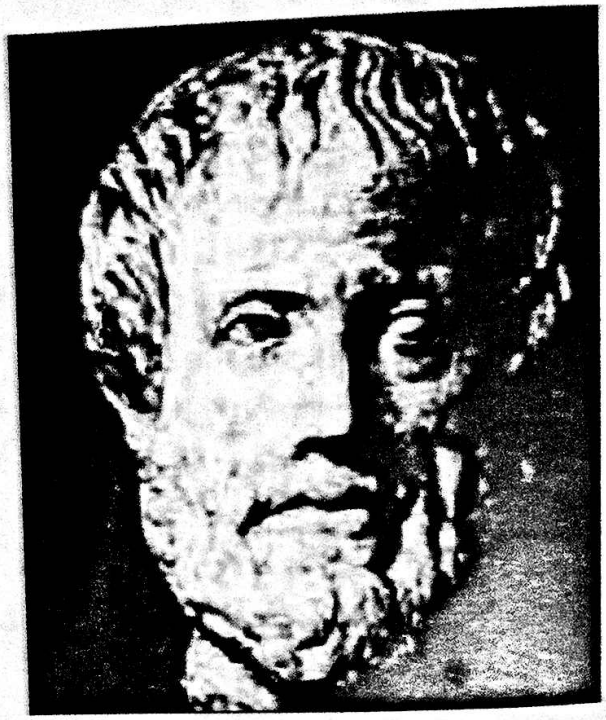
a) Record your thoughts on how a
why the results are similar and/
different.

ChemTalk

ATOMIC MASS

Atoms

In **Activity 2**, you defined the term element and explored the properties of some common elements. In this activity, you focused on atoms. An **atom** is the smallest representative part of an element. The ancient Greek philosopher Aristotle did not believe in the existence of atoms. In his thinking, if atoms did exist, there would have to be empty space between them.



Aristotle

Chem Words

atom: the smallest representative part of an element.

Aristotle did not believe it was possible to have empty space. Not everyone agreed with Aristotle. Another ancient Greek named Democritus believed that matter was made up of tiny particles that could not be broken down further. He called the particles atoms, from the Greek word *atomos*, meaning indivisible.

If you could have continued cutting the aluminum foil until it could no longer be cut, by any means, you would have reached one atom of aluminum. A mind-expanding fact is that if you started with 27 g of aluminum, you would find that there are 6.02×10^{23} atoms of aluminum. Nobody has ever counted this nor could they. Scientists have determined this number by other means and are very confident that it is correct.

Masses of Elements and Compounds in a Reaction

By the turn of the 19th century, chemists were combining elements to form new substances. The new substance was called a **compound**, because the atoms of the elements were believed to combine to form what they called a compound atom. The chemists were also particularly interested in measuring the amounts of elements used and substances formed. Their first attempts in determining masses were wrong, possibly due to the equipment that they had available at that time.

John Dalton, an early 19th century chemist who did much to advance the belief in the existence of atoms, expected that atoms combined in the simplest possible relationship. He reported that seven pounds of oxygen reacted with one

John Dalton

Chem Words

compound: a material that consists of two or more elements united together in definite proportion.

pound of hydrogen to form water. Accurate modern experiments give eight pounds to one. We will use modern values rather than historical ones to avoid confusion. Dalton reported that five pounds of nitrogen reacted with one pound of hydrogen to form ammonia. He also reported that seven pounds of oxygen reacted with five pounds of nitrogen to form a compound he called nitrous gas.

In 1809, Joseph Gay-Lussac reported that the hydrogen reacting with oxygen to form water occupied twice as much volume as the oxygen. He also noted that the hydrogen reacting with nitrogen to form ammonia occupied three times as much volume as the nitrogen. Furthermore, he found that equal volumes of nitrogen and oxygen reacted to form nitrous gas (now known as nitric oxide or nitrogen monoxide, NO).

Gay-Lussac's data was inconsistent with Dalton's assumption that water, ammonia, and nitrous gas are formed from one atom of each of the combining elements. This inconsistency was subsequently resolved by Amadeo Avogadro, who furthered the understanding of the correct chemical formulas and atomic masses.

Relative Mass of Atoms

Eventually, chemists determined a scale of relative masses of atoms through the systematic study of chemical reactions. By measuring the masses of two elements reacting with each other and knowing the formula for the compound that was formed, the relative mass of the two elements was determined. In this way, chemists were able to determine, for example, that one element has twice the mass of a second element. Relative mass does not tell you the exact mass measured in kilograms. It does provide a relative scale. Comparison of many reactions resulted in a scale of relative masses. Atoms of carbon were found to have a mass 12 times greater than the mass of hydrogen atoms, whereas oxygen atoms were found to have a mass 16 times greater than the mass of hydrogen. The units for this scale are called **atomic mass units**, defined in such a way that the mass of one type of carbon (carbon-12) is exactly 12 atomic mass units. The average mass of an atom of a given element in atomic mass units is known as the **atomic mass**. Atoms of hydrogen have an atomic mass of one unit. In addition to the physical and chemical properties of

Chem Words

atomic mass unit (amu): a unit of mass defined as one-twelfth of the mass of a carbon-12 atom.

atomic mass: atomic mass is determined by the mass of the protons and neutrons of the atom.

law of definite proportions: the composition of a pure substance is always the same or the elements of the compound always combine in the same proportion by mass.

Element	Relative atomic mass
Aluminum	26.98
Copper	63.55
Iodine	126.90
Iron	55.85
Magnesium	24.31
Silicon	28.09
Sulfur	32.06
Zinc	65.38

elements, the relative mass (incorrectly called weight) of each element was known and used by Mendeleev as he organized his table. The atomic mass is still one of the most prominent pieces of information provided for each element on the periodic table. The table gives the relative atomic masses of the eight elements that you observed in **Activity 2.**

Checking Up

1. What is the difference between an element and a compound?
2. What is an atom?
3. How is an atomic mass unit defined?
4. How can the existence of atoms help to explain the Law of Definite Proportions?

The Law of Definite Proportions

Chemists at the beginning of the 19th century noted that eight pounds of oxygen always reacted with one pound of hydrogen to form nine pounds of water. This observation is an example of **The Law of Definite Proportions.** This law, first articulated by Joseph Proust in 1799, states that whenever two elements combine to form a compound, they do so in a definite proportion by mass. Proust based this statement on his observations that 100 pounds of copper, dissolved in nitric acid and precipitated by carbonates of soda (sodium) or potash (potassium), invariably gave 180 pounds of green carbonate. The Law of Definite Proportions is not direct proof of the existence of atoms. However, if you believe in the existence of atoms it does make it easier to explain why the Law of Definite Proportions should hold. The existence of atoms can also help explain why a given mass of aluminum reacting with sufficient copper (II) chloride in solution should always produce the same mass of copper.